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Review

New Frontiers of Electronic Theses and Dissertations

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Abstract: (1) Background: Since the 1990s, theses and dissertations—a key part of scientific communication—have evolved significantly with advances in information and communication technologies. (2) Methods: This study reviews 99 publications examining these changes, drawing insights from international conferences and empirical studies in the field. (3) Results: Historically, a major challenge in managing PhD theses has been the shift to electronic formats, resulting in the creation of electronic theses and dissertations (ETDs). This shift involves four main tasks: adopting new digital formats, updating institutional workflows between departments, graduate schools, and academic libraries, implementing updated bibliographic standards (such as metadata and identifiers), and utilizing new tools and channels for distribution. With open science becoming a widespread research policy across many countries and institutions, ensuring open access for ETDs is an added challenge—though a substantial portion of ETD content remains restricted to institutional or library networks. Today, ETD management is on the brink of a new era, with advancements in data-driven science and artificial intelligence. (4) Conclusions: The development of ETDs varies significantly across different countries, regions, and institutions due to technological, organizational, and legal differences. It is essential for academic libraries and other stakeholders to address the challenges identified while considering these variations.

Keywords: electronic theses and dissertations; digitization; open access; institutional repositories; research data; metadata; artificial intelligence; academic libraries; higher education institutions; library and information science

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1. Introduction

After the emergence of the first universities in the 12th and 13th centuries, scholastic education and having a degree became a pathway to career opportunities [1]. However, assessing students for qualifications and degree attainment posed a challenge. Various methods were employed to evaluate students, including asking questions [2]. Another approach involved requiring a comprehensive scientific investigation known as a thesis or dissertation. While the first theses and dissertations (TDs) were written in Europe, the first dissertation in America was completed in 1861 at Yale University [3].

TDs, created at the culmination of a period of study and research, remain a core requirement for higher academic degrees, particularly the PhD and Masters. Being the outcome of "focused, extensive and in-depth research work of several years, involving intellectual labour by scholars and their supervisors" [4], they are rich and unique sources

of scholarly information, a vital part of the historical record of graduate education at higher education institutions, and regarded as the "bedrock of graduate education" [4–6].

Twenty-five years ago, the worldwide production of TDs was estimated at at least 100,000 each year and up to 200,000 when considering all countries [7]. Yet, precise estimates are difficult. The ProQuest Dissertations and Theses Global database increases in size by 250,000 works each year (PQDT: https://about.proquest.com/en/products-services/pqdtglobal/, accessed on 13 November 2024), while the Bielefeld Academic Search Engine references annually 170,000 to 180,000 doctoral and postdoctoral theses (BASE: https://www.base-search.net/about/en/index.php, accessed on 13 November 2024).

Despite the significant number of TDs created annually and their valuable content, these works have often been difficult for academic communities to find and access. Many TDs remain locked away in library shelves or published in formats that are not easily discoverable. Peter Suber described TDs as "the most invisible form of useful literature and the most useful form of invisible literature" [8]. In their print form, "the vast majority of these works languish in obscurity in college and university libraries and archives" [5]. This lack of visibility limits their potential impact on research and society.

However, both the form and content of TDs have evolved significantly since the 1990s, presenting new challenges where the electronic format plays an important role [9]. The move from print to electronic theses and dissertations (ETDs) has been described as a "global move" with significant advantages for all stakeholders, like a "better preparation for the up-and-coming community of young researchers [. . .]; increased visibility of individual as well as university research [. . .]; and broader collaboration inside and among universities"—in short, "a 'win-win' situation (where) everyone saves money and receives benefits" [10].

The shift from print to digital was enabled by decades of effort from academic librarians, computer scientists, scholars, and students. This transition sparked conversations about format, workflows, metadata, preservation, and dissemination, with significant support from professional and academic networks such as NDLTD (Networked Digital Library of Theses and Dissertations: https://ndltd.org/, accessed on 13 November 2024) and USETDA (United States Electronic Thesis and Dissertation Association: https://www.usetda.org/, accessed on 13 November 2024). Numerous conferences, seminars, workshops, and training materials have contributed to these discussions [3]. Also, there is a growing body of research on ETDs, articles, conference papers, and other sources especially in the fields of computer and social sciences, with a focus on digital libraries and institutional repositories, which are useful in understanding ETDs [11,12].

For more than 15 years, the digital world has become the "new normal" [13]. Also, the environment and the challenges for the production, management, and usage of TDs have fundamentally changed. This review offers an analysis of the evolution of ETDs across three key phases: the transition from print to digital, the shift toward open access, and the growing significance of data. The conclusion presents recommendations for future practice and research on ETDs, with a particular focus on the role of artificial intelligence (AI).

2. Methods

This article provides a review of the evolution of research on ETDs over the past three decades, drawing insights from empirical studies—primarily published in academic journals—and from international conferences in the field. It draws on sources from the Web of Science (WoS) Core Collection, as of 15 July 2024, with the query "electronic theses and dissertations" in the title, covering articles, proceedings, and chapters—a total of 60 items. The WoS was selected for its reputation as a reliable source of the literature that is high-quality and peer-reviewed in the fields of science, technology, and social sciences.

This database allows for structured indexing and citation tracking, facilitating a systematic exploration of the literature. For the WoS query, quotation marks were used to refine the search. Without them, the results would have included over 700 references, and nearly 5000 references with "theses" OR "dissertations", many of which were irrelevant.

Our primary aim was to review the evolution of the field of ETDs and we selected the term "electronic theses and dissertations" to design our search query. The term "electronic theses and dissertations" is widely recognized and has been consistently used in the literature since the advent of digital formats for academic work. This specific terminology does not have widely accepted synonyms; for instance, while "digital theses and dissertations" can be used, it lacks the same level of recognition in the academic community. By focusing on "electronic theses and dissertations", our search captured the most relevant literature, as this term has appeared in the titles of the majority of studies related to this field.

Additionally, a search conducted on Google Scholar (GS), also on 15 July 2024, using the query "electronic theses and dissertations" (without quotation marks) in the title resulted in 366 items, ranging from 1996 to 2024. GS was included in our search strategy due to its broad coverage of the academic literature across various disciplines and languages. GS indexes a wide range of sources, including theses, dissertations, reports, and the grey literature, which may not be captured in traditional databases. By utilizing both databases, we aimed to balance the rigor of the peer-reviewed literature with the breadth of available research.

This review is further supplemented by research papers, presentations, and related files from the annual symposia of the NDLTD (NDLTD Symposium Papers, Slides, and Posters; https://ndltd.org/thesis-resources/etd-symposium-papers-slides-and-posters/, accessed on 13 November 2024). The NDLTD, particularly through its ETD symposia, has amassed a significant number of papers from outside North America, which partly corrects the bias of the WoS.

The review prioritized international research published in English, which introduced a linguistic bias. This decision stemmed from the aim of addressing an international audience, with English serving as the scientific lingua franca. Similarly, NDLTD, for instance, chose to accept and share only papers, posters, and slides in English.

Following a manual selection process, 99 items were identified as the most relevant through manual deduplication (we did not use any software). Since our objective was not to conduct a systematic review but rather to provide a holistic view of the evolution of ETDs, we did not conduct a duplicate removal process. Instead, we carefully selected specific studies based on their relevance to our research question, and only unique studies were included in our analysis. The 99 references constitute the corpus of the review. All selected and reviewed references are cited and included in the bibliography (the bibliography contains three references [13–15] that are not part of the reviewed sample but contribute to the understanding of the context of the development of ETDs).

The papers were analyzed using qualitative content analysis, emphasizing key themes (e.g., digitization, open access, data, and metadata), purposes and anticipated benefits, enabling and hindering factors, challenges and limitations, specific issues tied to particular contexts (case studies), and future outlooks. Based on discussions and the consensus among all authors, we extracted the final schema that reflects the key findings and themes identified in the literature. With a corpus of approximately 100 papers, employing text-mining software was deemed neither necessary nor particularly insightful. Due to the small size of the corpus, we took care to avoid making hasty generalizations (the law of small numbers) and refrained from generating precise statistics on the distribution of topics.

3. Results

The selected references span the years 1996 to 2024, averaging four papers per year. Figure 1 shows their time distribution.

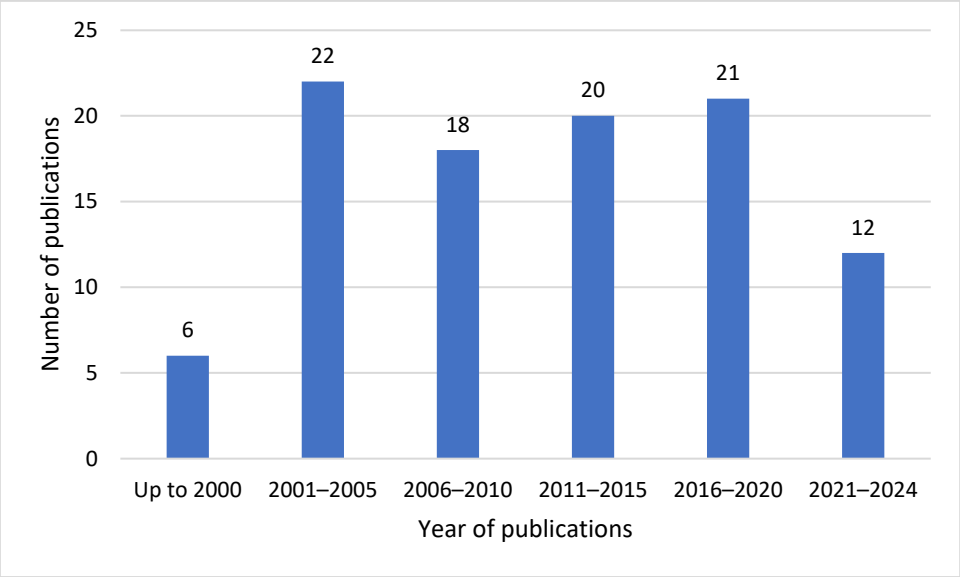

Figure 1. Year of selected publications on ETDs (sample = 99 items).

Compared to the initial Google Scholar sample of 366 references and due to the manual selection, the period of 2001–2005 is slightly overrepresented while the period of 2021–2024 is underrepresented. More than 40 papers are from non-English speaking countries.

3.1. From Print to Digital

For many years, the primary challenge in handling PhD theses was converting them into electronic format, known as ETDs. This process typically involves five main tasks: adopting new digital document formats, updating institutional workflows across departments, graduate schools, and academic libraries, establishing new standards for bibliographic descriptions (including metadata and identifiers), exploring innovative methods for dissemination via various tools and channels, and changing the culture from print to electronic. The technological drive for this idea was first explored during a workshop in the fall of 1987 in Ann Arbor, Michigan [16], while the first relevant papers on ETDs were published a little bit later, from 1995 onward. This topic was prominent in the early 2000s but continues to appear in recent papers. Table 1 provides an overview of potential benefits, challenges, issues, and concerns.

Table 1. From print to digital TDs: benefits, challenges, and concerns.

Potential Benefits	Challenges, Issues, and Concerns
Improved availability	New culture required
Larger audience	New formats, standards, and workflows
Improved impact and usefulness	Lack of skills, knowledge, and awareness
Empowering students	Insufficient technical and financial resources
Reduced processing costs	Additional workload
Reduced shelf space for storage	Long-term preservation
More timely public access	Legal and ethical concerns

3.1.1. Promises and Benefits

Many studies provide arguments in favor of the move from print to digital. The main argument why universities should require ETDs is that "making theses and dissertations available electronically dramatically widens their exposure and usefulness" [3]. With the advent of ETDs, more TDs are being read, reaching a significantly larger audience than when they were stored in paper format by university or national libraries [17].

The assumption is that the transition to ETDs promotes scholarly communication in general and helps empower students in particular: "We hope that students will more rapidly gain recognition. We hope that worldwide collaboration will expand, even across boundaries of language. We hope that new discoveries will more quickly be built upon, by researchers located anywhere on the globe, leading to new scholarship and useful technology transfer. We hope that world understanding will increase" [16]. In other words, ETDs are a kind of "knowledge discovery tool", especially in multilingual settings [18].

For academic libraries, this shift has several specific advantages, like, among others, a better stocked global digital library, improved availability, and more timely public access to current research, fewer physical copies to handle, less shelf space required for storage, reduced processing costs (including microfilming) [19], and the potential to "serve more users with reduced staff" [20].

Also, rather early, this move from print to digital is considered essential, self-evident, and ineluctable. Also, based on empirical evidence from 13 field studies with US and Canadian universities, George Soete from the Association of Research Libraries concludes that ETDs are an inevitable development: "Though many institutions are taking it slow, their ultimate goal, clearly, is required submission of ETDs and, ultimately, a paperless thesis and dissertation program" [21].

3.1.2. Challenges

Pilot projects, such as the Electronic Manuscript Project (with UMI), Virginia Tech's task force on ETDs [16], or the JISC Electronic Theses project [22], along with studies on the transition from print to digital TDs, identified a couple of main challenges, such as the need for a new culture of academic publishing and the requirement of new workflows, bibliographic descriptions, and formats [7,23].

The move to ETDs requires a new culture of scholarly publishing [24]. The focus should not only be on institutions but, more importantly, on students: "A significant factor in advancing ETDs and other digital library projects is shifting the program emphasis to key participants, the graduate students who author these documents" [25].

Pilot projects, such as the Electronic Manuscript Project, were initiated to explore innovative ways to enhance the accessibility and usability of ETDs. The technological drive for this idea was first explored during a workshop in the fall of 1987 in Ann Arbor, Michigan. At this event, Nick Altair, Vice President for UMI and involved in the Electronic Manuscript Project, raised the question of how SGML could be applied to dissertations. Responding to this challenge, Gary Hooper was convinced to invest USD 5000 of Virginia Tech funds, and work began with a graduate student and Yuri Rubinsky from SoftQuad.

While Virginia Tech launched a task force to consider workflow and cataloging guidelines [20], for the period from 2002 to 2004, the JISC funded a pilot program that evaluated "a wide range of existing practices of e-theses production, management, and use against a set of criteria to develop models for use within the UK information environment" [22].

Academic institutions, particularly libraries, had to develop new workflows for managing ETDs. It quickly became clear that there are two types: the first is a native digital file, created and submitted by the student using tools like Microsoft Word or LaTeX, in its final approved form. The second is a scanned version of a paper thesis or dissertation,

usually produced by university staff or a service provider. This format is less favorable due to its larger file size, limited searchability, lack of flexibility, and missed opportunity for students to gain experience with electronic publishing [26]. This second category also includes retrodigitized older theses, representing scientific heritage with its own unique requirements and challenges [27].

From the outset, the need for new suitable formats for ETDs was evident. "By 1988 we had the first Document Type Definition for ETDs, and a few dissertations were 'marked up' using SGML and the new DTD", a process similar to formatting a thesis in HTML or XML [14]. These new formats allowed for the integration of multimedia, combining text, graphics, animation, and sound in a cohesive way [7]. For example, Humboldt University in Berlin implemented an XML-based workflow, enabling Master's and doctoral students to create and submit ETDs incorporating multimedia elements like sound, images, and animation [28,29].

The transition from print to digital formats also necessitated new standards and tools for managing ETDs, such as the ETD-MS metadata standard, which aligns with Dublin Core [10].

3.1.3. Case Studies and Best Practices

Several studies have documented ETD projects through case studies and surveys in diverse settings. Research has been conducted in countries such as Brazil [30], the Czech Republic [31], India [32,33], Korea [34,35], Nigeria [36], Zimbabwe [37], and other African nations [38–40]. A survey of best ETD practices, particularly in the USA, was published in 2002 [41] while Linda Goodfellow and her colleagues explored the implementation of ETD workflows in nursing schools [42,43].

Despite varying circumstances, projects, and methodologies, these studies consistently emphasize common challenges: the initial lack of knowledge and skills among students, faculty, and staff, the critical role of effective communication and human factors [44], the need for training, and the growing interest in institutional repositories to enhance the visibility of local research.

To address these challenges, comprehensive reference works and guidelines on managing ETDs have been published for academic institutions, libraries, and students. These resources cover key aspects such as terminology, workflows, production, submission, cataloging, copyright, and long-term preservation [26,45].

UNESCO also published a guide on ETDs, particularly aimed at developing countries. The guide was based on the recognition that "of its 187 member states, at least two-thirds remain uninformed about both the amplified access to current scholarship provided by ETDs and the benefits of involvement in ETD initiatives". The guide's mission is threefold: to raise awareness among member states, foster a positive attitude, and initiate action plans at the national or regional level [41,46].

3.1.4. Concerns and Critics

Some studies expressed substantial concerns about ETD programs, such as additional workload, insufficient resources, and issues with long-term preservation and copyright. For instance, Susan Copeland reported a "key concern voiced by some faculty members and supervisors centred on the potential extra work that would be required of students" [17]. Additional concerns were raised regarding the required resources and skills: the ETD system "works only if (students, researchers, and others) have access to the necessary computer resources and know-how" [47]. At the 2003 ETD symposium, similar concerns were highlighted on a global scale, particularly regarding the challenges faced by developing countries [48].

At the same conference, two other topics sparked debate and concern: the advantages of national versus institutional ETD programs, and more specifically, the challenges of long-term preservation and archiving [48]. While a few case studies from different contexts provide insights into necessary workflows, standards, and tools (Germany: [49]; Algeria: [50]), Strodl et al. [51] evaluated the effectiveness of various preservation strategies in meeting the requirements for preserving theses and dissertations. Teper and Kraemer [52] emphasized the institutional responsibility for long-term preservation, which may conflict with other ETD program goals like ease of production and accessibility.

Another challenge in the shift from print to digital formats has been the reluctance of students, concerned that publishing houses might reject their work. While this concern may have merit, surveys conducted with editors and publishers offered a more balanced view [53] (see below).

The primary objective of these and similar studies is to raise awareness and address the identified issues and concerns. Only a few studies have highlighted more significant problems or provided critiques of ETD programs. One notable issue is the lack of a sustainable business model for both institutional and national ETD programs [54–57]. Two other critical concerns are the limited impact of ETDs and the coercive nature of some programs.

Larivière et al. [58] present empirical evidence showing that the impact of theses as information sources has generally declined over the last century. They argue that there is no evidence that ETDs have positively influenced this trend, and in fact, the introduction of ETDs has coincided with a more rapid decline in thesis impact.

Hawkins et al. [59] raise ethical concerns regarding mandatory open access (OA) policies. They critique practices of "coercion", "propagandistic assurances to students that it's ok to give away their work", and "manipulative practices", whether intentional or not. They also highlight "ethical faults" in these programs and advocate for an alternative approach. This alternative would prioritize respect for students' intellectual property and institutional transparency, aligning more closely with the ethical treatment of students and their work.

3.2. Toward Open Access

3.2.1. "Low-Hanging Fruit"

With the rise of open science as a prevalent research policy in numerous countries and institutions, ensuring open access became another challenge, if not a priority for ETD programs: "With more organizational interest in the growing Institutional Repository movement, the links between ETDs and institutional repositories is not only natural but well positioned as open access and archival preservation techniques become common in electronic and scholarly publishing" [60]. Papers addressing issues related to open access (OA) have been published since 2001 and continue to be released to this day.

As the number of born-digital TDs increases, and as they are generally "royalty-free works of research literature, (and) not formally published" [61], ETDs should be considered "low-hanging fruit for the OA movement" [8]. Also, Ed Fox and his colleagues argue that it is relatively simple for a university to provide open access to its ETDs: "Usually the university libraries host the ETDs and support the full information cycle including prolonged open access. Many universities have broad digital library efforts, or specialized institutional repositories" [10]. Even so, as a case study from Indiana University shows, such a project presents a number of obstacles and that "finding solutions to these issues (can) be a challenge" and that networking with other universities proves to be helpful [62]. Table 2 provides an overview of the potential benefits and limitations of open access and repositories.

Table 2. Toward open access: benefits and limitations.

Potential Benefits	Limitations
Improved visibility and accessibility	Undefined policies
Increased usage and impact	Restricted access
Valorization of students	Insufficient metadata quality (including persistent identifiers)
Potential for AI tools	Insufficient standards
Increased content quality	Long-term preservation

3.2.2. Benefits

Open access ensures that the knowledge produced by students during their time at the university contributes to the broader body of scholarly research. It eliminates the limitations of time and location that are typically associated with print TDs stored in libraries or academic departments. The University of Nebraska found a 60-fold increase in the use of open-access dissertations, compared to ones that were not open-access; while West Virginia University's ETDs are accessed 145% more than their printed counterparts [63].

ETDs also offer significant value to students by providing a publicly accessible citable version of their academic work. They can showcase this research to potential employers and academic institutions in resumes and CVs, offering students a verified demonstration of expertise and a lasting record of their early scholarly work, complete with a stable URL [22].

A couple of surveys and studies show that the concern about publishing opportunities, especially in STM, appears to be largely unwarranted and reveal, for instance, that more than half of a sample of science journals reported that manuscripts derived from openly accessible ETDs are "welcome for submission", while nearly a third "would accept revised ETDs under certain conditions" [64–66]. Yet, especially in the Humanities, in fields where the monograph remains the primary form of scholarly communication, some publishers remain reluctant to consider works that are available as ETDs due to the perception that the online availability reduces the novelty and marketability of the content [64,67].

3.2.3. Limitations

Over the years, ETDs have become the most frequent document type in institutional repositories, after journal articles were accepted by more than 55% of the repositories [4,10]. However, many repositories have "explicitly undefined metadata policies, content submission policies, and preservation policies and these are very serious issues in the management of ETDs" [4], and a significant part of ETD content remains restricted or inaccessible beyond institutional or library boundaries, under embargo, confidential, or restricted to campus access, or simply not available at all, because of different reasons, like intellectual property, legitimate interests, expected exploitation, and trade secrets, but also simple lack of awareness [68–70]. For this reason, Peter Suber argues for mandating open access to ETDs: "Mandates work and exhortations don't. This is the universal lesson from OA mandates to date, whether at funding agencies or universities" [8].

3.2.4. Other Issues

Other studies have been published on web analytics [71], search strategies [72], and reference link rots of ETDs [73,74]. A recent Master's thesis in computer sciences showed how artificial intelligence, i.e., chapter-level classification using machine learning and deep learning techniques, can improve ETD accessibility [75]. More generally, it has been said that "openness is not enough" for the dissemination of ETDs through institutional repositories and that the content and metadata quality, standard formats, interoperability, and appropriate services are required for the efficient processing and impact of ETDs [76].

Open science presents both opportunities and challenges for ETDs. It enhances their visibility, accessibility, and openness, particularly within open repositories. However, it also highlights and exacerbates common issues associated with ETDs, such as the lack of persistent identifiers, issues with metadata quality and richness, and difficulties with long-term preservation.

3.3. The Increasing Role of Data

Currently, ETD management is entering a new era, embracing the data-driven science approach known as Jim Gray's "Fourth Paradigm" [14], which includes research data management and the application of FAIR principles. In the context of ETDs, "data" refers to two distinct types: the content of TDs and their metadata. Recognizing this, a research team from Virginia Tech presented a model for large-scale harvesting of both ETD content (data) and metadata to create an extensive ETD collection for research purposes [77]. Papers on data-related issues have been published for the past 20 years, but their significance has grown notably since 2015. Table 3 provides an overview of related issues.

Table 3. Data and metadata: issues.

Data	Metadata
Rich and unique sources of scientific information	Importance of quality control
Potential data for Text and Data Mining (TDM) and AI	Need for standardization and interoperability (FAIR principles)
Access to related research data	Relevance for research information management

3.3.1. Research Data

Dissertations and theses can be an invaluable resource for academics and PhD students in the same field, often providing more detail and a more comprehensive literature review than journal articles. Recently, ETDs have gained increasing attention as large datasets for research, particularly with the use of new text and data mining (TDM) techniques. These data are an interesting resource for researchers investigating the development and volume of graduate works in specific subject areas, career trajectories of graduate students, or the general evolution of language [71].

Thus, ETDs can be regarded as research data and utilized accordingly, provided that technical and legal conditions are met. However, these conditions may vary across countries and institutions. Regarding the TDM of scientific content, country-specific inconsistencies concerning the legal basis and potential copyright conflicts should be addressed to create a stable environment for better research opportunities [71].

Based on an analysis of hundreds of PhD theses in the social sciences and humanities, three data-related dimensions of ETDs have been identified [78]: those with links to research data (with the risk of link rot), those containing research data (raising concerns about formats, identification, and copyright), and those considered as research data (raising technical and legal issues related to TDM). The significant potential of ETDs in research data management has been demonstrated through a couple of research projects [79].

3.3.2. Metadata

Several studies highlight the importance of metadata quality in managing and disseminating ETDs. The central premise is that higher-quality metadata enhances discoverability—sometimes overlapping with full-text data [80]—and boosts accessibility and usage of ETDs [81]. While metadata quality control is widely considered essential, its precise definition remains unclear. For instance, a survey found general agreement on

using fields like title, abstract, type, author, and subject, but there was disagreement on the importance of controlled vocabulary [82].

The surveys also reveal a wide variation in metadata policies, practices, formats, and standards, impacting the findability and interoperability of ETD repositories and collections [83–86]. Specific attention has been given to subject analysis [87] and the use of persistent identifiers like ORCID [88].

Other studies propose models and methods to improve ETD metadata standardization, richness, and interoperability. For instance, a semi-automated process has been designed to extract student-supplied metadata from the OhioLINK ETD Center, to enhance it using the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH), and to integrate it into the library catalog [89]. Catalog librarians then finalize the records and contribute them to OCLC WorldCat as well as local and consortium catalogs. Another project to automate aspects of metadata record creation utilizes a modified version of MarcEdit to convert student-supplied Dublin Core metadata into MARC format for exporting to the library's online catalog and WorldCat, streamlining the creation and editing of MARC records through automated processes [19].

A French research team examined the use of ETDs and their metadata in research assessment and research information management systems [90], while a team from Malaysia compared the interoperability protocols of ETD repositories [91]. Additionally, the FAIRness of ETDs has been explored [92], relating to the FAIR principles for research data management [15].

4. Discussion

The transition from print to ETDs appears to be a global trend, with three major periods (Figure 2). However, case studies, surveys, and papers, particularly from international ETD symposia organized by the NDLTD, depict a fragmented landscape characterized by diverse programs, models, and outcomes. Only a few large-scale initiatives, such as the NDLTD Global ETD Search and ProQuest Dissertations and Theses Global, provide cohesion. The brief history of ETDs has been far from uniform. While some countries and institutions have successfully adopted 100% digital TD, others continue to face challenges in meeting the legal, organizational, and technical requirements for implementing ETD programs. Assessments of existing programs also reveal significant variations in metadata formats and quality [85].

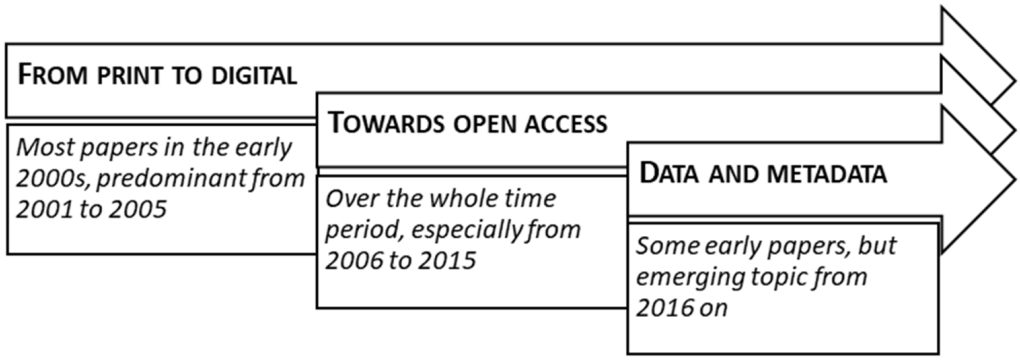

Figure 2. Timeline of ETD-related topics.

Numerous barriers hinder the effective implementation and development of ETD programs, including technology acceptance, resource availability, and concerns over future publication, copyright issues, plagiarism, and sensitive content [93,94]. While graduate students and supervisors generally support ETDs, their lack of skills and the aforementioned concerns may prevent them from fully embracing the programs [93]. Additional

challenges include the uncertain quality of TDs [93], inadequate support services, and low user satisfaction with ETD repositories [95].

On a broader scale, the lack of cooperation poses a serious threat to national and institutional ETD programs. Fostering cultural and institutional collaboration is crucial for the success of ETD initiatives [96]; while legislative mandates can encourage participation [8], genuine institutional commitment is vital for an ETD program's long-term success. Similarly, a Nigerian case study asserts that the poor management of ETD initiatives is responsible for the limited global visibility and accessibility of these research outputs [97].

Despite the wide variation in ETD programs and outcomes and the advances in legal and technological frameworks, the shift from print to digital has not fundamentally altered the role of theses and dissertations. They remain a core requirement for higher degrees, especially PhDs, and are the product of years of focused in-depth research and intellectual collaboration between scholars and their supervisors [4]. However, this could change with the advent of artificial intelligence, which, undoubtedly, following the waves of digitization, open access, and data management, represents the next frontier in ETD development.

Given our current understanding of AI, it is reasonable to anticipate that AI tools will enhance the referencing, dissemination, and discoverability of ETDs. This could be achieved through automatic indexing and categorization based on content, topics, and metadata, as well as AI-driven tools for language translation, recommendation systems, and technologies like natural language processing and machine learning algorithms, which could boost the efficiency and accuracy of ETD searches. Additionally, other AI tools might extract insights, identify patterns, analyze trends, generate summaries, and automate data extraction from documents. Six recent papers provide valuable insights into AI's expanding role in this field.

A study about chapter-level classification using machine learning and deep learning techniques to improve ETD accessibility has been mentioned above [73]. Large language models can enhance metadata quality by automatically detecting, correcting, and standardizing scholarly metadata, as demonstrated in a case study using the MetaEnhance framework [98], especially based on information provided by the ETD cover pages [99]. ChatGPT has been employed to generate Library of Congress Subject Headings for ETDs based on their titles and abstracts, suggesting that such tools have the potential to reduce the cataloging time and to improve their discovery in academic libraries [100]. AI can also assist developers and decision-makers in redesigning ETD systems by leveraging context-aware technologies to meet user needs, recommend relevant documents, retrieve user-specific content, and improve system compatibility, thus enhancing the usability of ETDs [101]. Another study highlights AI's ability to analyze large collections of ETDs by automatically extracting figures and tables [102].

Additionally, the study demonstrates how ETDs can serve as valuable training data for AI tools through machine learning techniques, emphasizing their role as rich and unique sources of scholarly information. The near future will show how AI tools will reshape the creation, processing, dissemination, and use of ETDs. However, these AI advancements are not exclusive to ETDs; it is possible that current expectations are overly optimistic, and we may need to pass through a "trough of disillusionment" (as described in Gartner's Hype Cycle) before we learn to apply these tools effectively and reasonably to ETDs.

5. Concluding Remarks

Theses and dissertations, essential components of higher education, especially for PhDs, represent years of focused research and intellectual effort. Historically, these works, rich in scholarly content, were largely hidden in physical archives and less accessible. Over the course of the last three decades, the shift from print to digital has transformed the

accessibility and visibility of these information resources. This "global move" to ETDs offers significant advantages, including better preparation for researchers, increased visibility for universities, and broader collaboration, benefiting all stakeholders. This transition to digital was driven by academic communities and networks like NDLTD [10,24], which addressed challenges related to format, preservation, and dissemination.

The review highlights three key phases in the evolution of ETDs: the transition to digital formats, the rise of open access, and the increasing importance of data, with a particular emphasis on the role of artificial intelligence in future research. Numerous case studies from different countries showcase the global development of ETDs and the significant variations between countries and institutions. Over time, the focus has shifted from early advocacy and implementation challenges—such as workflows, formats, staffing, and IT—to open access, institutional repositories, metadata quality, and data management, including the use of persistent identifiers. While long-term preservation remains a concern, AI has emerged as a new area of interest.

So, what is next? Given the diverse landscape of global ETD programs, three recommendations can help prevent further digital divides and fragmentation:

1. Library and information scientists, along with academic librarians, should facilitate empirical assessments of ETD programs by creating a standardized conceptual and methodological framework. This framework should emphasize metadata and persistent identifiers, usage and impact metrics, and long-term preservation and ensure that institutional repositories are FAIR and trustworthy;
2. Scientists and librarians should strengthen the global ETD community of practice by establishing an ETD observatory—an online platform for researchers, information professionals, and service providers. This platform would enable the analysis and discussion of ETD program development, advocate for their integration into the changing landscape of academic publishing, and provide support through information sharing and training, considering diverse local and regional contexts;
3. Scientists and librarians should closely monitor the effects of AI on the creation, processing, dissemination, and utilization of ETDs. While technology is a key factor, legal, ethical, and political issues also need urgent assessment;
4. There is a need for research and tools focused on increasing the usability of ETDs. For example, efforts should be made to develop citation analysis methodologies suitable for ETDs and establish specific metrics to assess their usability. This will enhance the understanding of how ETDs are utilized and their impact on the academic community.

For years, the NDLTD has been central in coordinating the global ETD community, promoting knowledge sharing, best practices, and standards discussions. This role remains essential, and NDLTD seems to be the most suitable organization to lead the future development of the ETD community.

On the institutional level, academic libraries should foster the development of trustworthy repositories and of interoperable ETD workflows, while PhD training programs should systematically include open science, research data management, and issues related to digital formats and metadata (standards, persistent identifiers).

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